MIYARES

An Additional Water Supply for the City of Danville

Civil Engineering

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AN ADDITIONAL WATER SUPPLY FOR THE CITY OF DANVILLE

BY

JUAN PORTUONDO Y MIYARES

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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COLLEGE OF ENGINEERING.

May 24, 1912

This is to certify that the thesis of JUAN PORTUONDO Y MIYARES entitled AN ADDITIONAL WATER SUPPLY FOR THE CITY OF DANVILLE was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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Recommendation approved:

Ira O. Baker.
Professor of Civil Engineering.

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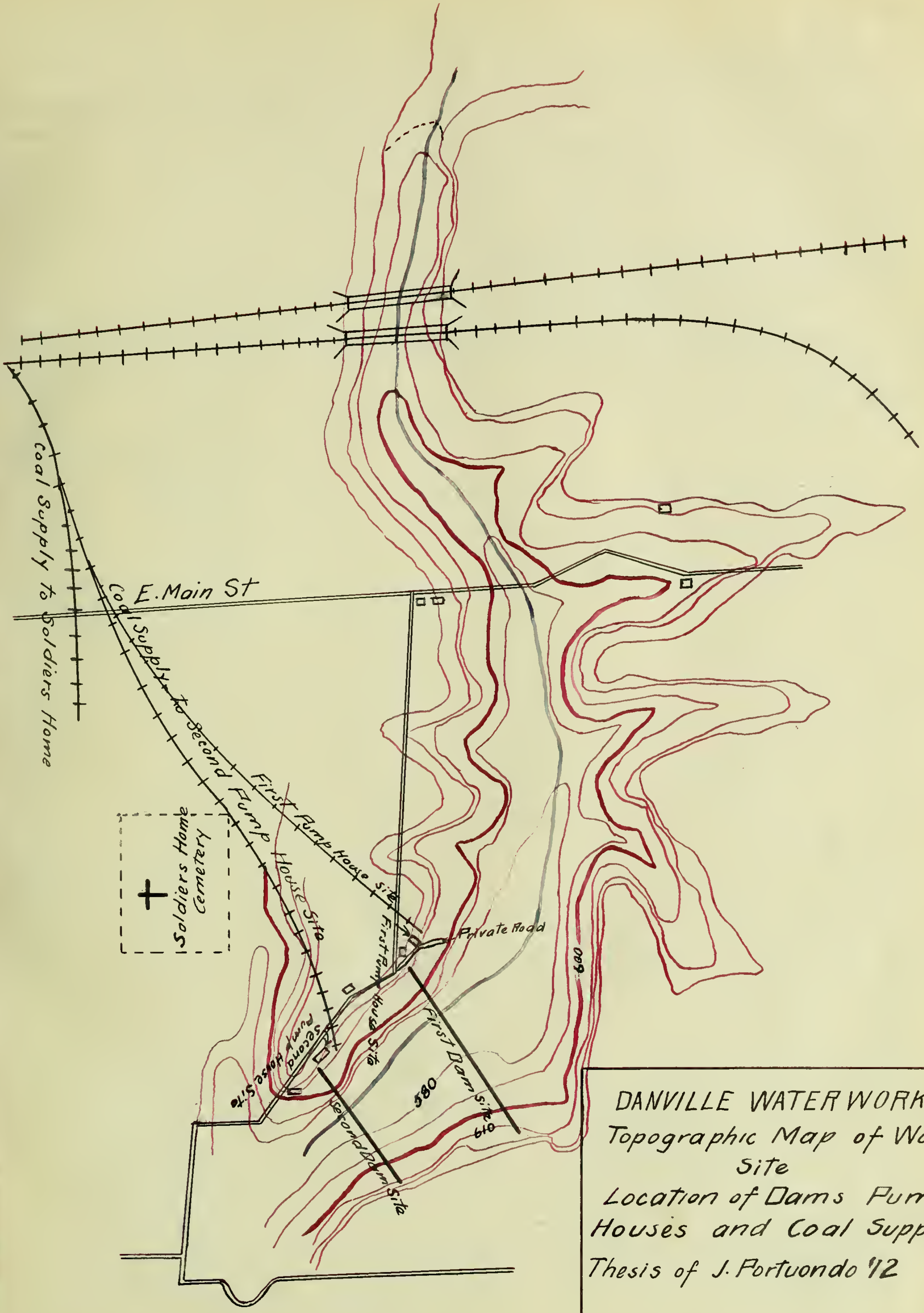
INTRODUCTION.

In the preparation of this thesis on an Additional Water Supply for the City of Danville it was not possible to obtain complete information of all sources of water supply available for the city of Danville, Illinois. It was assumed that it would be necessary to secure additional supply from surface streams and it was also assumed that the additional supply must be sufficient to supply one-third of the city. Recent rapid growth in urban population has made the furnishing of public water supplies of extraordinary importance. In such work exact mathmatics cannot solve every problem and one must rely upon good judgement aided by experience.

The writer has found it difficult to collect rainfall and run-off data for the vicinity of Danville. The rainfall in nearby counties has been plotted and from these the average for Danville has been estimated.

Drainage Area.

The map of the Danville quadrangle of the United States Geological Survey was used and all available drainage areas within eight miles of Danville were studied to determine their suitability as a source of supply. Lick Creek about three miles East of the center of Danville appeared to be the best source of supply. The writer made a visit to this site and walked over several miles of the drainage area and followed about two miles along the course of the stream. From this examination and the examination of the map it was not condidered possible to find a better site. The drainage area is mostly cultivated. The ground is largely stony clay with pockets and thin layers of sand and



DANVILLE WATERWORKS
Topographic Map of Works Site
Location of Dams Pump Houses and Coal Supply
Thesis of J. Fortuondo '12

gravel and a thin surface capping of pebbleless clay. The valley of the creek is of alluvium and the area slopes gently toward the banks. The northern part of the area has a slope of about 50 feet to the mile. The southern part of the drainage area is almost flat except for the banks of the creek. The best locations for a dam were about 3000 and 4000 feet south of East Main St. and close to the Soldiers Home as shown on page 2 . The drainage area above the down stream site is 9.4 sq. miles and the drainage area above the other site is 9.3 sq. miles. Estimates were made for both locations.

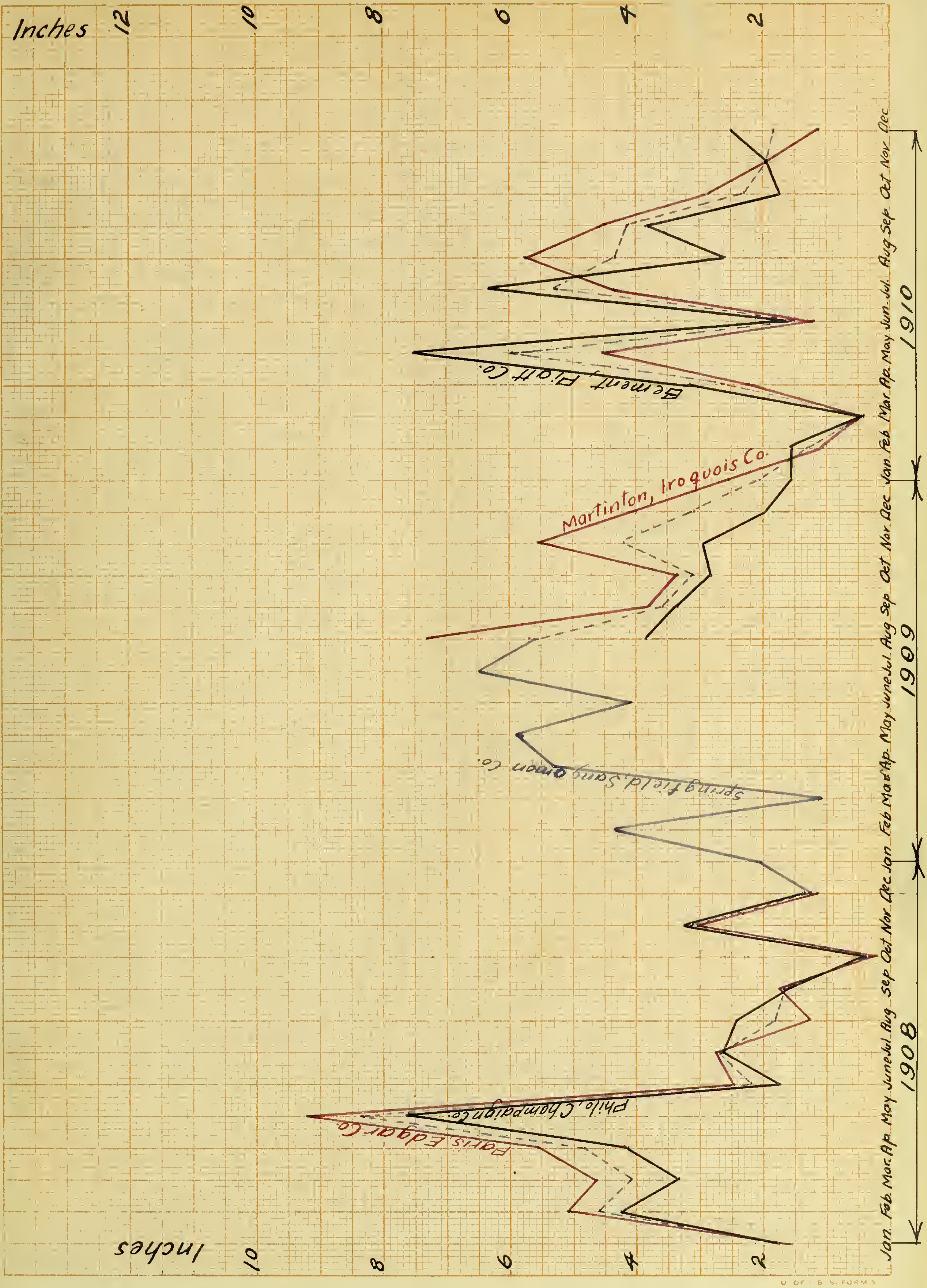
Rainfall and Run-off.

No exact data on rainfall has been secured for that locality but it is estimated from data for neighboring localities in which rainfalls are about the same as for Danville. The great variation of rainfall makes it necessary that a careful study for a long period of time be made. In the case at hand data for Philo, Champaign Co., Paris, Edgar Co., Springfield, Sangamon Co., Martinton, Iroquois Co., and Bement, Platt Co. were plotted. See page 5 .

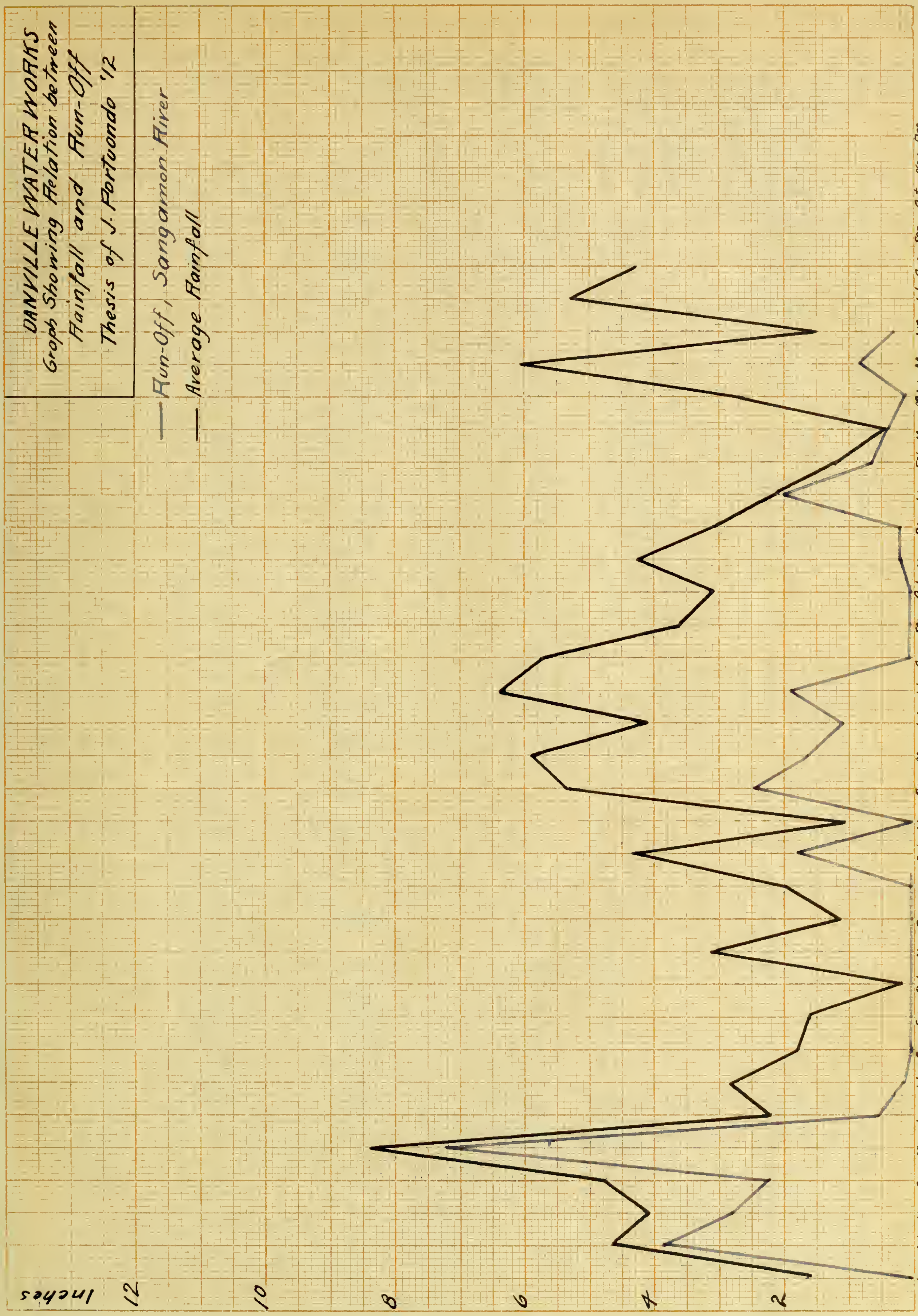
In estimating the run-off the minimum that might occur must be considered. The amount of rainfall, nature of the soil, slope of the surface, the geologic structure and the amount of forest should be considered. As no data relating to this Particular locality was found the writer was compelled to accept data from localities which were similar to the one at hand and fortunately in the book, "Surface Water Supply of Illinois for 1908-1910", data of the gaging of Sangamon River near Monticello were obtained. Having these data and knowing the rainfall at the time that these gaugings were made the percentage of rainfall collected was calculated. A table giving rainfalls and runoff collected and diagrams for rainfall and run-off are given on pages 4 , 5, and 6.

Estimate of percentage of rainfall collected in Sangamon River near Monticello, Ill

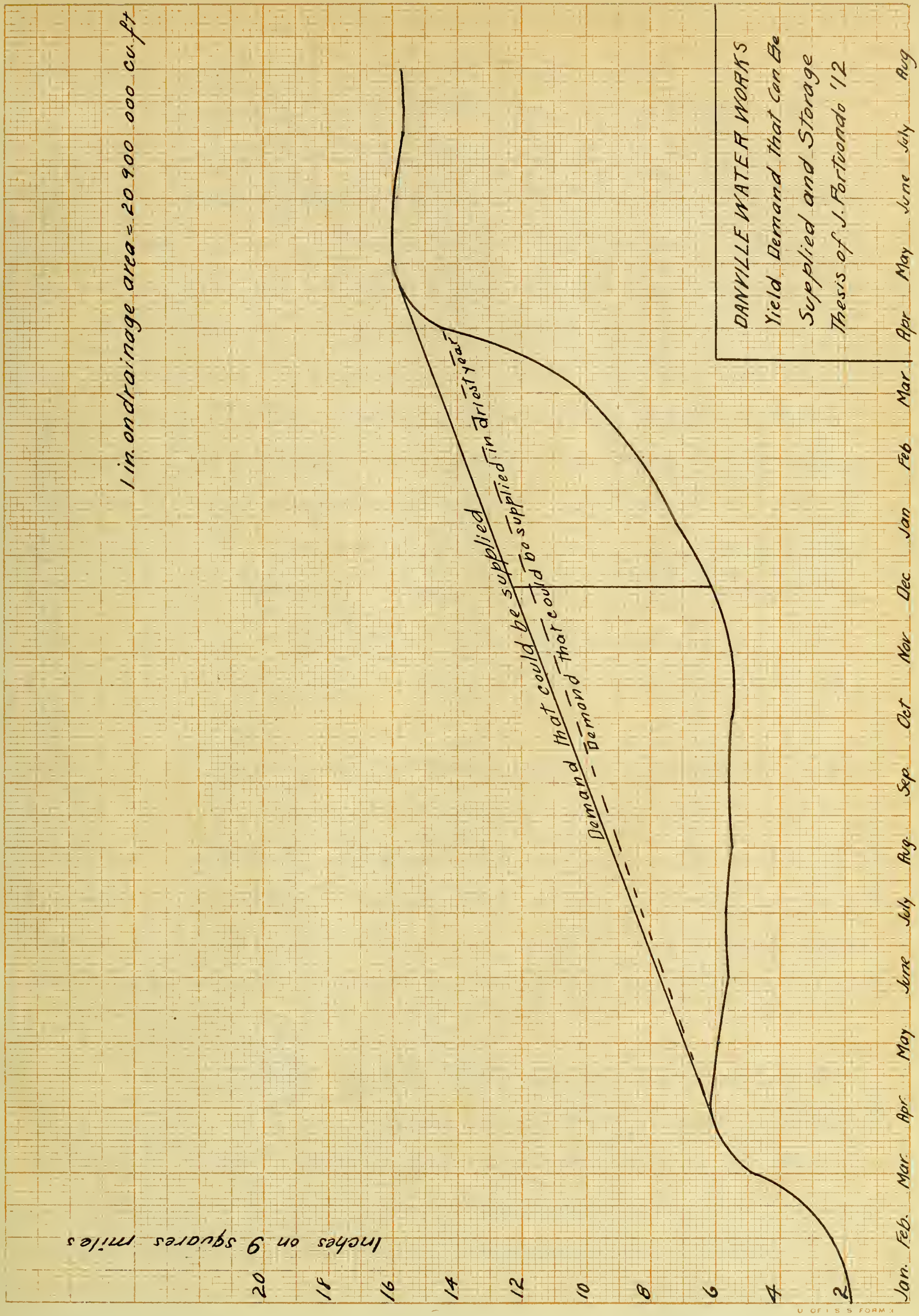
		Flow			In. of Rainfall From Av. on page 5	Runoff		Percentage Collected
		Max C.F.S	Mean C.F.S	Min C.F.S.		Cu. Ft. per Sec. per Sq. Mile	Ins.	
1908	Jan.	37	16.8		4.65	.036	.032	1.94
	Feb.	4250	1890.0	194.0	4.65	3.44	3.84	82.5
	Mar.	2760	1380.0	562.0	4.15	2.51	2.8	67.5
	Apr.	3120	1120.0	505.0	4.75	2.04	2.3	48.5
	May	9820	3610.0	870.0	8.40	6.7	7.2	86.0
	June	756	260.0	82.0	2.20	.474	.53	2.41
	July	138	58.0	25.0	2.80	.105	.10	3.86
	Aug.	25	13.2	8.0	1.80	.024	.03	1.48
	Sep.	11	7.0	6.0	1.60	.012	.01	.84
	Oct.	11	7.3	6.0	.25	.013	.01	5.8
	Nov.	25	13.0	11.0	3.10	.023	.03	.83
	Dec	31	14.0	11.0	1.15	.025	.03	2.43
1909	Jan		16.8		2.00	.036	.04	2.04
	Feb		932.0		4.3	1.70	1.76	41.0
	Mar		556.0		2.1	.08	1.12	53.0
	Apr.		1210.0		5.3	2.2	2.46	46.4
	May		738.0		6.9	1.34	1.64	23.8
	June		556.0		4.1	1.00	1.12	27.3
	July		954.0		6.4	1.74	1.95	30.4
	Aug		40.4		5.7	.07	.01	1.49
	Sep		15.9		3.6	.02	.03	.89
	Oct		17.7		3.1	.03	.04	1.15
	Nov		109.0		4.3	.20	.22	5.2
	Dec		101.0		3.1	.18	.21	6.66
1910	Jan		980.0		2.1	1.8	2.00	95.0
	Feb		330.0		1.2	.6	.67	56.0



U. OF I. S. S. FORM 3


DANVILLE WATER WORKS
Graph Showing Relation between
Rainfall and Run-Off
Thesis of J. Portuondo '12
— Run-Off, Sangamon River
— Average Rainfall
Inches
12
10
8
6
4
2
Jan
Feb
Mar
Apr.
May
Jun.
Jul.
Aug
Sep
Oct
Nov
Dec
1908
Jan
Feb
Mar
Apr.
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1909
Jan
Feb
Mar
Apr.
May
Jun.
Jul.
Aug
Sep.
Oct
Nov
Dec
1910

	Month.	Rainfall. Inches	Evaporation. Inches.	Rainfall Collected. Inches.	On Reservior. Rain -fall less Evaporat-ion. Ins.	Equiv. Net Yield on 9 sq.mi, Ins.	Total Yield. Ins.
1901	Jan.	2.50	.74	1.8	1.7	1.88	1.88
	Feb.	1.21	.59	.6	.1	.60	2.40
	Mar.	3.37	.83	2.5	1.3	2.56	4.96
	Apr.	1.89	.67	1.2	-2.8	1.87	6.03
	May	0.69	.65	0.0	-3.2	-.15	5.88
	Jun.	3.86	3.82	0.0	-.5	-.02	5.86
	Jul.	2.65	4.19	0.0	-2.8	-.13	5.73
	Aug.	0.70	3.09	0.0	-2.8	-.27	5.46
	Sep.	2.63	2.38	0.3	-1.9	.21	5.67
	Oct.	0.71	1.66	0.0	-2.8	-.13	5.54
	Nov.	1.87	.87	0.2	-1.9	.11	5.43
	Dec.	1.75	.67	1.1	-.3	1.11	6.54
1902	Jan.	1.08	.43	0.7	0.2	.71	7.25
	Feb.	1.50	.50	1.0	0.4	1.02	8.27
	Mar.	2.45	.69	1.8	0.4	1.82	10.09
	Apr.	5.63	1.59	4.0	1.0	4.04	14.49
	May	4.41	3.05	1.4	0.6	1.43	15.92
	Jun.	2.26	3.40	0.0	-2.1	-0.09	15.83
	Jul.	3.13	4.40	0.0	-2.3	-0.10	15.7
	Aug.	4.26	4.08	0.2	-2.3	0.10	15.8
	Sep.	3.99	2.78	1.3	-0.6	1.27	17.0
	Oct.	1.99	1.23	0.7	-1.5	0.63	17.6
	Nov.	0.97	0.84	0.1	-1.9	0.0	17.6
	Dec.	0.95	0.57	0.4	-o.5	0.38	17.9



DANVILLE WATER WORKS
Yield, Demand that Can Be
Supplied and Storage
Thesis of J. Fortuondo '12

Capacity of Reservoir and necessary Height of Dam.

As stated in the introduction it was assumed that the east one-third of Danville was to be supplied from this additional water supply. The population was secured from United States Census Reports and is given on page 24 . The future increase in population was estimated as 30% for every ten years. The population of Danville has been increasing at a more rapid rate but it was not considered that the present high rate would continue. Other cities in Illinois, of from twenty to sixty thousand in population show an increase of about thirty per-cent. The adverage consumption will probably be about 100 gallons per capita per day. To store water above an elevation of 610 would give more shallow water than a lower elevation and at a higher elevation the line of East Main St. would have to be moved and its grade would have to be changed for a considerable distance. Two or three houses would have to be moved if the water surface was above elevation 610.

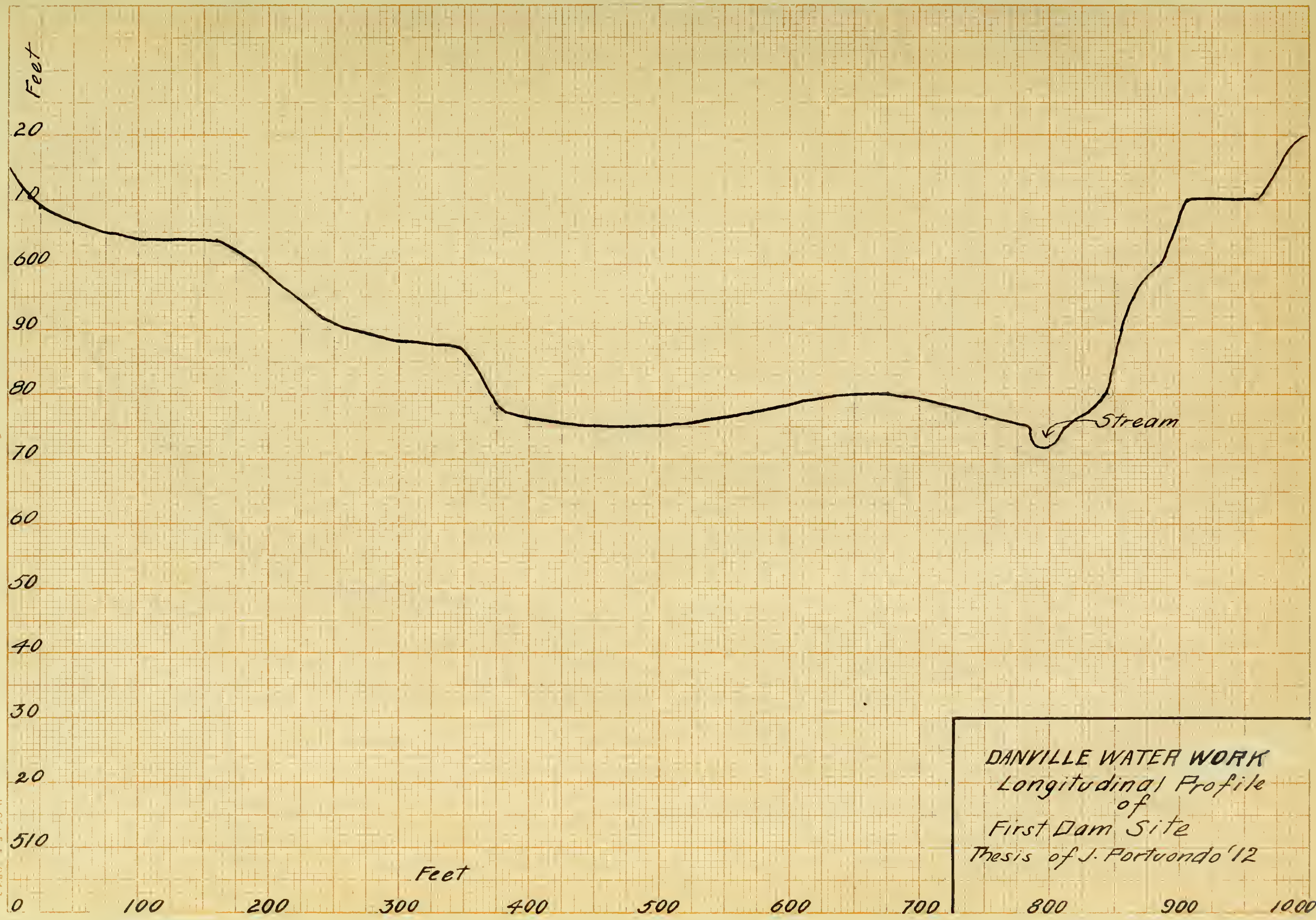
From data on pages 4- 6 , from calculations of evaporation by Vermeule's formula and from data for evaporation from water surface at Springfield, Illinois, the estimated yield of the drainage area was calculated as given on page 8 . The rainfall was taken for the year 1901 and 1903 for Rushville, Illinois and would give the maximum size of storage reservoir needed, 1902 was ommitted as it was a very wet year.

The yield showed that a demand of 16,000,000 cubic feet per month could be supplied. Examination of data in the book, "Surface Water Supply of Illinois", 1908-1910, the driest successive years for various towns were chosen and assuming the same percentage run-off as given on page 7 ,it was estimated that a demand of

14,000,000 cubic feet per month could be supplied.

The storage necessary for this demand would be 150,000,000 cubic feet. Storing water up to an elevation of 600 would give a capacity of 96,000,000 cubic feet and storing water to an elevation of 610 would give a capacity of 184,000,000 cubic feet. It was decided to store water to an elevation of 610 giving a reservoir of sufficient size to allow considerable filling by sediment of the stream. This will also allow for leakage. To supply the present population a very much smaller reservoir will be sufficient but with the rapid increase in population it was deemed best to supply this for as many years in the future as possible. 14,000,000 cubic feet per month would probably be sufficient to supply the demand for 40 or 50 years.

To allow for a depth of water flowing over the spillway the top of the dam is at an elevation 615. Computations of storage capacity follow.



DANVILLE WATER WORK
Longitudinal Profile
of
First Dam Site
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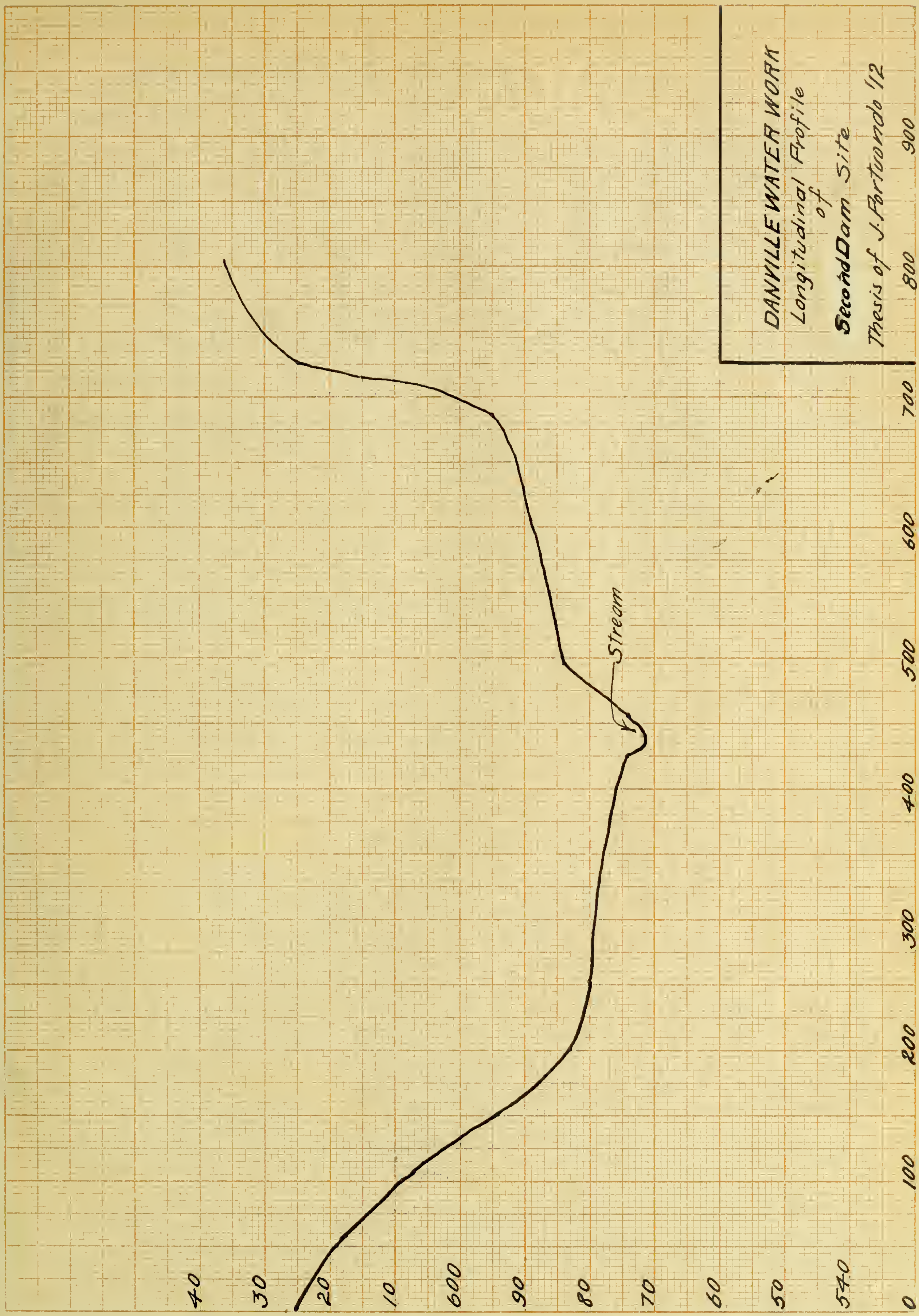


DANVILLE WATER WORK
Longitudinal Profile
of
Second Dam Site
Thesis of J. Portuondo '12

U OF I S S FORM

Amount that Reservoir Can Store.

First study

Area of 610 contour-------------------------- 9,824,000 sq. ft.
" 600 " --------------------------5,730,000 " "
" 590 " --------------------------4,240,000 " "
" 580 " -------------------------- 1,340,000 " "

Amount that reservoir can hold ----1,192,000,000 gallons

Second study

Area of 610 contour---------------------------10,930,000 sq. ft.
" 600 " ---------------------------6,730,000 " "
" 590 " ----------------------------4,940,000 " "
" 580 " -------------------------- 1,895,000 " "

Amount that reservoir can hold-----1,378,000,000 gallons

Dams.

The two best sites for dams were given in the paragraph on drainage area and are shown on page 2 . The dam will be constructed of rolled earth, the water side having a slope of 3 to 1 and that of the down stream side a slope of 2 to 1. The water side will be paved with rip rap ½ cu.ft. or less in size placed by hand to a fairly uniform thickness of six inches. On this rip rap broken stone will be spread to a depth of four inches and trimmed to an even slope. The cost is estimated at $.90 per cubic yard. The dimensions of the dam at each site are given on pages 15,16. In comparing the two sites it was estimated to be 15 feet from the surface to impervious ground . To prevent percolation a trench 10 feet wide will be excavated to impervious material and filled with puddle. The earth of either excavation will be classified as " easy earth". The earth excavated will be dumped about 500 feet from the dam along the creek banks. The cost per cubic yard will be estimated at $.40. The cost of placing puddle was estimated to be $ 1.60 per cubic yard.

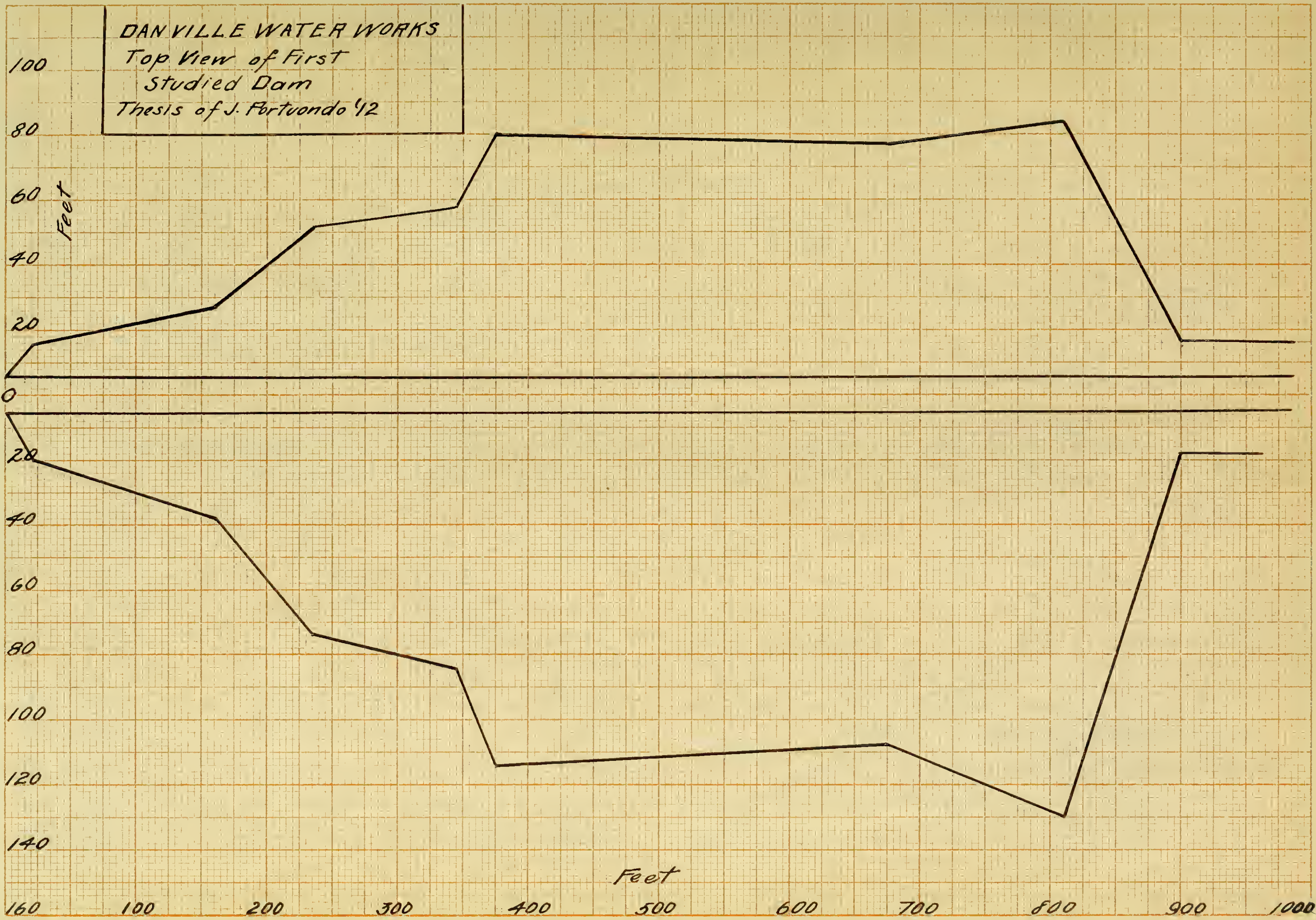
The following table gives an estimate of the cost of a dam at each site.

Dam.	Excavation cu,yds.	Excavation cost of,	Cost of puddle wall	Amt. earth for dams. cu. yds.	Cost of Dam.	Amt. of r.r.	Cost of r.r.
First site.	8660	$3569	$ 7920	87812	$52600	2275	$2050
Second "	6250	2500	6350	68545	41100	1513	1361

In making this estimate unit prices were chosen as follows.

Foreman....................	$0.024
Hauling....................	0.240
Labor......................	0.200
Sprinkling.................	0.014
Picking Stones.............	0.019
Trimming slopes............	0.008
Tools,blacksmithing,powder.	0.047
	0.560
Supertendence and Engineering..........	0.035
Protecting for winter	0.005
	$ 0.600

The cost per cubic yard of stone is assumed to be $.90



DANVILLE WATER WORKS
Top View of First
Studied Dam
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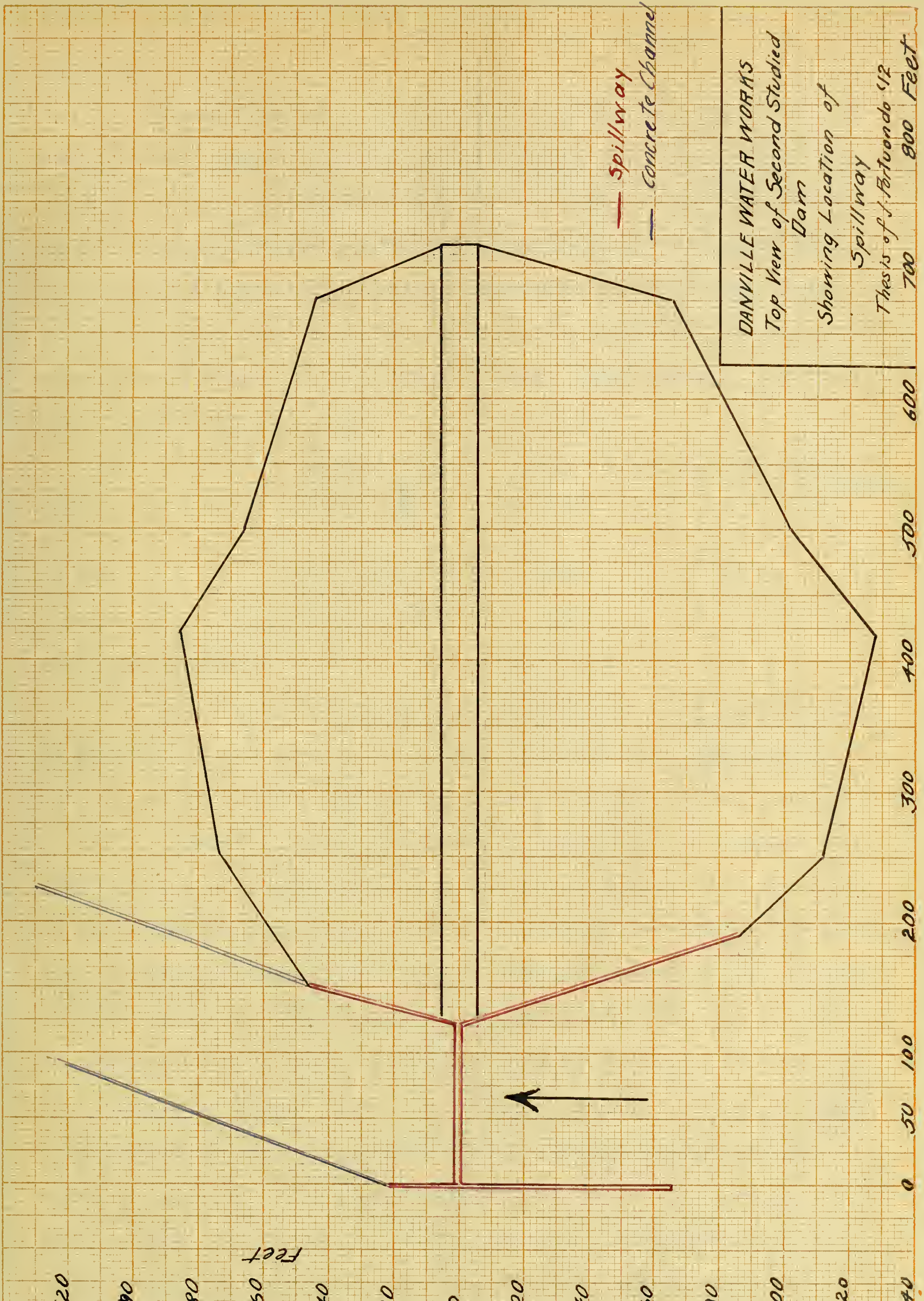
U. OF I. B. S. FORM 3



DANVILLE WATER WORKS
Top View of Second Studied Dam
Showing Location of Spillway
Thesis of J. Portuondo '12

U. OF I. E. S. FORM 3

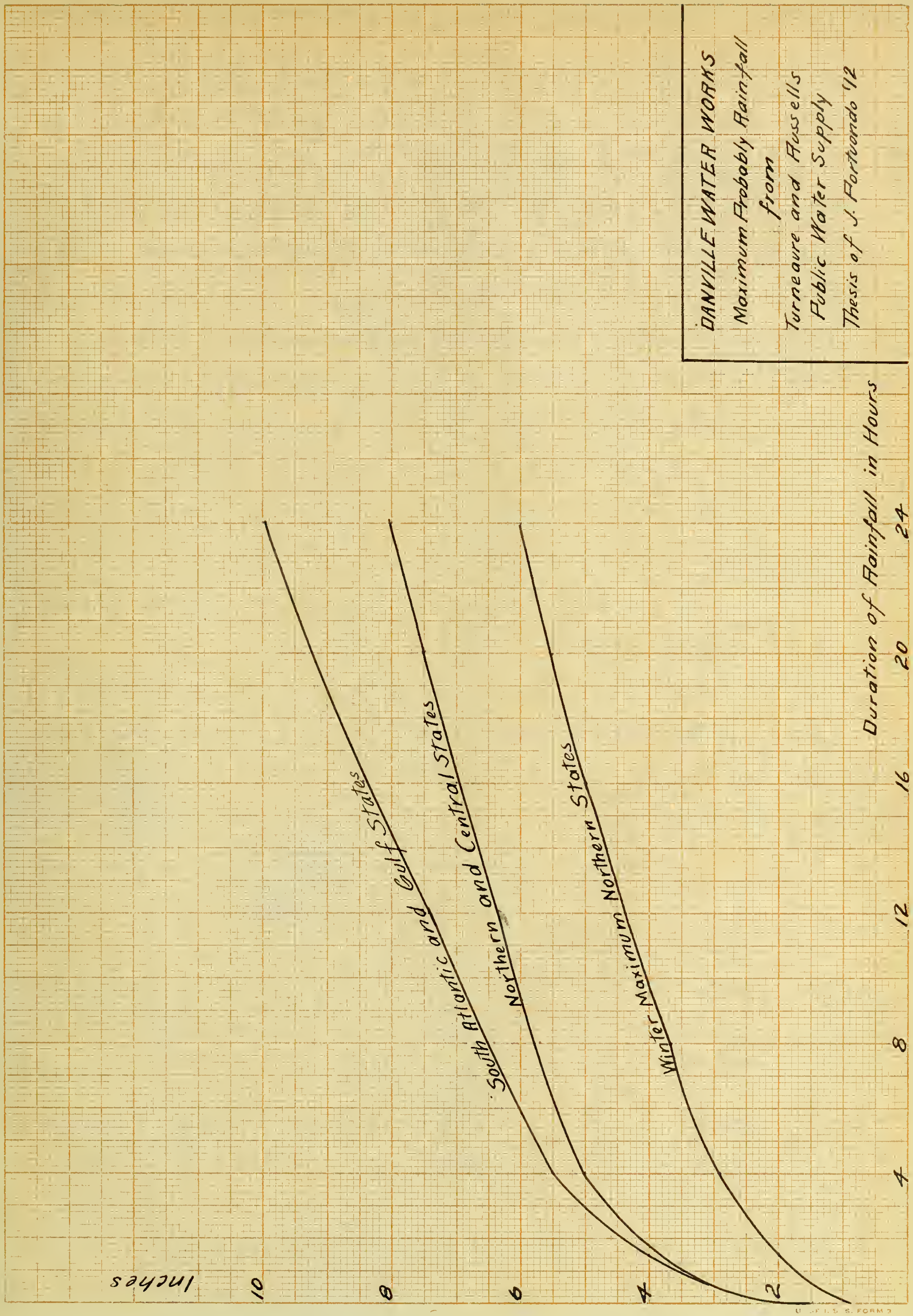
Spillway.

A spillway must be provided capable of passing off the maximum storm run-off. It is hence necessary to know what the maximum rate of run-off will be. For the maximum run-off to be used in calculating the size of the spillway several empirical formulae were used giving values differing one from the other. The rational method has also been calculated, the result of which the writer finally used. The following table shows results secured by use of empirical formulae.

Name	Formula	Run off in cu. ft. per sec. per sq.mi.
Fanning	$Q = 200 \frac{M^{5/6}}{M}$	137
Dredge	$Q = 1300 \frac{M}{L^{2/3}}$	500
Cooley	$Q = 180 \frac{M^{2/3}}{M}$	85

Rational Method.

The farth~~er~~est point of the drainage area from spillway is about 4 miles. Nearly the entire drainage area was inspected and the United States Geological Survey contour map was stuied. It was estimated that the water would take about 75 minutes to flow one mile. It would then require about 5 hours for the water to flow from the farthest point of the drainage area to the sipillway. A maximum rate of rainfall of one inch per hour for a period of five hours was used and the maximum rate of run off of 35% of the rainfall. This gives a maximum rate of run-off of 232 cu. ft. per second per square mile. The rate of rainfall chosen is from data collected from the United States Monthly Weather Review as shown on page 18. This run-off might not occur in a century, but will be used in the design of the spillway. An overflow of the earth dam would be disastrous and whatever the width of the



DANVILLE WATER WORKS
Maximum Probably Rainfall
from
Turneaure and Russells
Public Water Supply
Thesis of J. Fortuondo '12

U. OF I. S. S. FORM 3

spillway the same sidewall will be necessary. The total maximum run off from the drainage area will be equal to 2100 cubic feet per second. For the length of the spillway the formula $Q = 3.33L\ H^{3/2}$ was used. The length of spillway and the amount of water to flow over it demand careful consideration. The elevation of the top of the spillway and not that of the dam decides the elevation of the water surface in the reservior and hence the amount of storage provided. The water should never reach such a level that its waves can rise above the top of the dam, which must therefore be higher than the spillway by an amount equal to the greatest depth of water on the spillway plus the greatest heigth of waves possible. Therefore the greater the depth of flow in spillway the more costly the dam and the greater the areathat will be flooded.

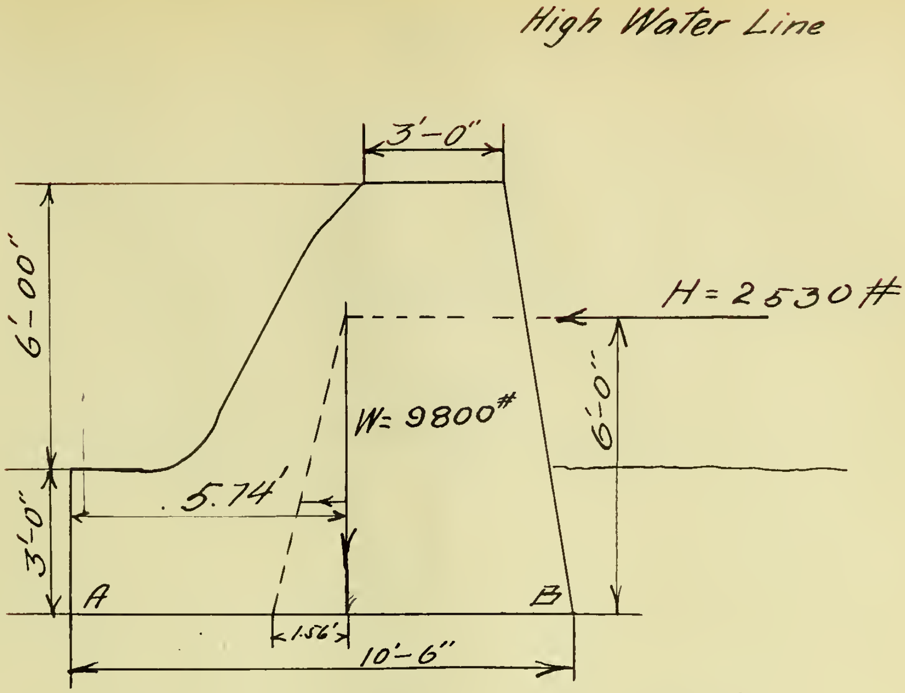
The spillway will be made of concrete. There will be a channel 200 feet long paved with cement so the water will not erode the earth on the down stream side and endanger the dam. Computations for stability and plan are given on page 20. Computations are made for the second location only. The reason for selecting this site is given under Final Location of Plant.

The amount of concrete in the spillway.

	Cu. yds. of concrete	Cost
Wingwalls------------------	199.0	1592.0
Spillway------------------------	293.0	2344.0
Channel -------------------------	474.0	3792.0
Retaining Walls----------------	256.0	2048.0
Total --------------------	1122.0	9776.0

Pumping Plant.

The maximim amount of water that can be supplied from

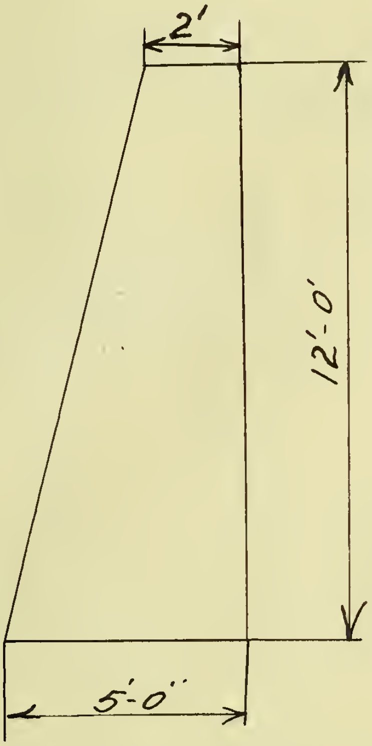


Area of Section = 65.7 Sq. ft.

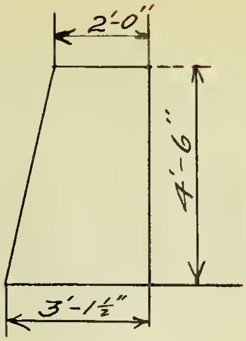
Weight of one foot section = 9800#

$P_A = +1500$ $P_B = +364$

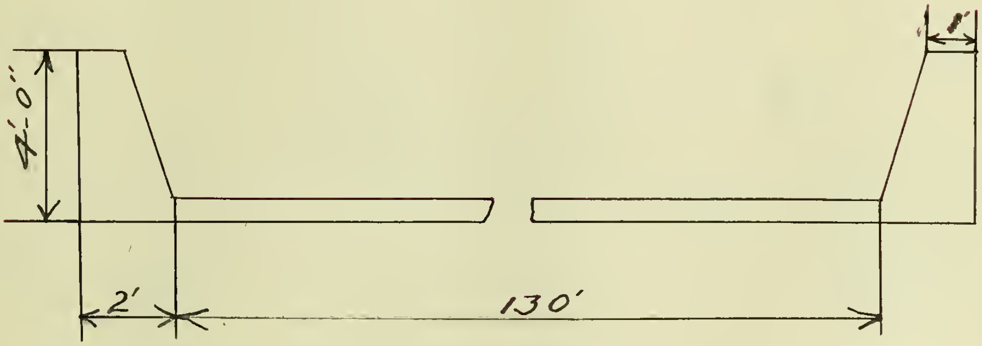
Section of Spillway



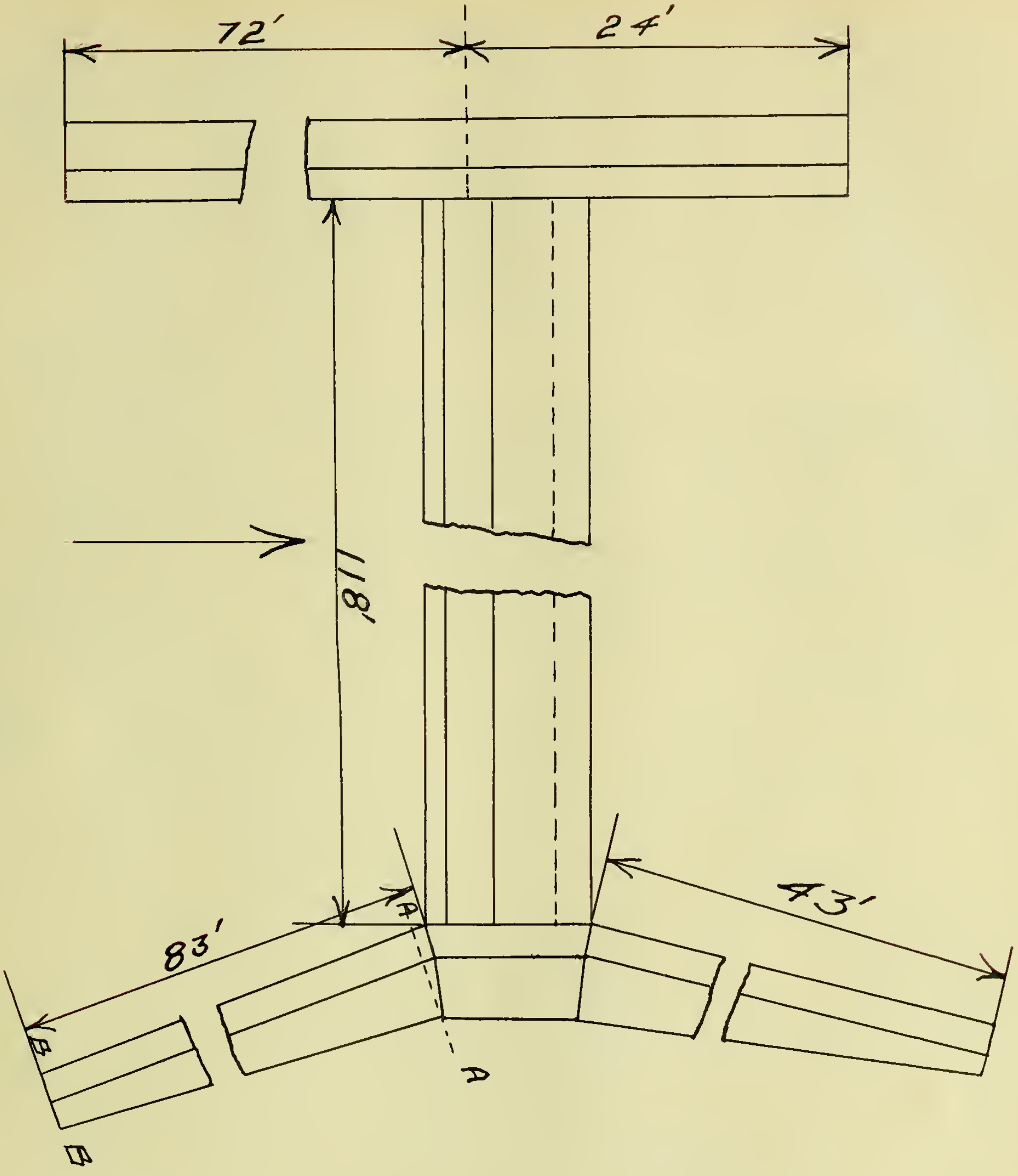
Wing Wall Section A-A page 22



Section at B-B page 22



Channel Section



Plan Showing Spillway
and Retaining Walls

this work will be for a population of 30,000 inhabitants. Assuming that the average consumption equals 100 gallons per day per capita the daily consumption will be 3,000,000 gallons or 125,000 gallons per hour. But this consumption varies at certain hours of the day reaching sometimes the amount of 175% of the average. 3,000,000 x 1.75 = 5,250,000 gallons per day ,or 219,000 gallons per hour for domestic use.

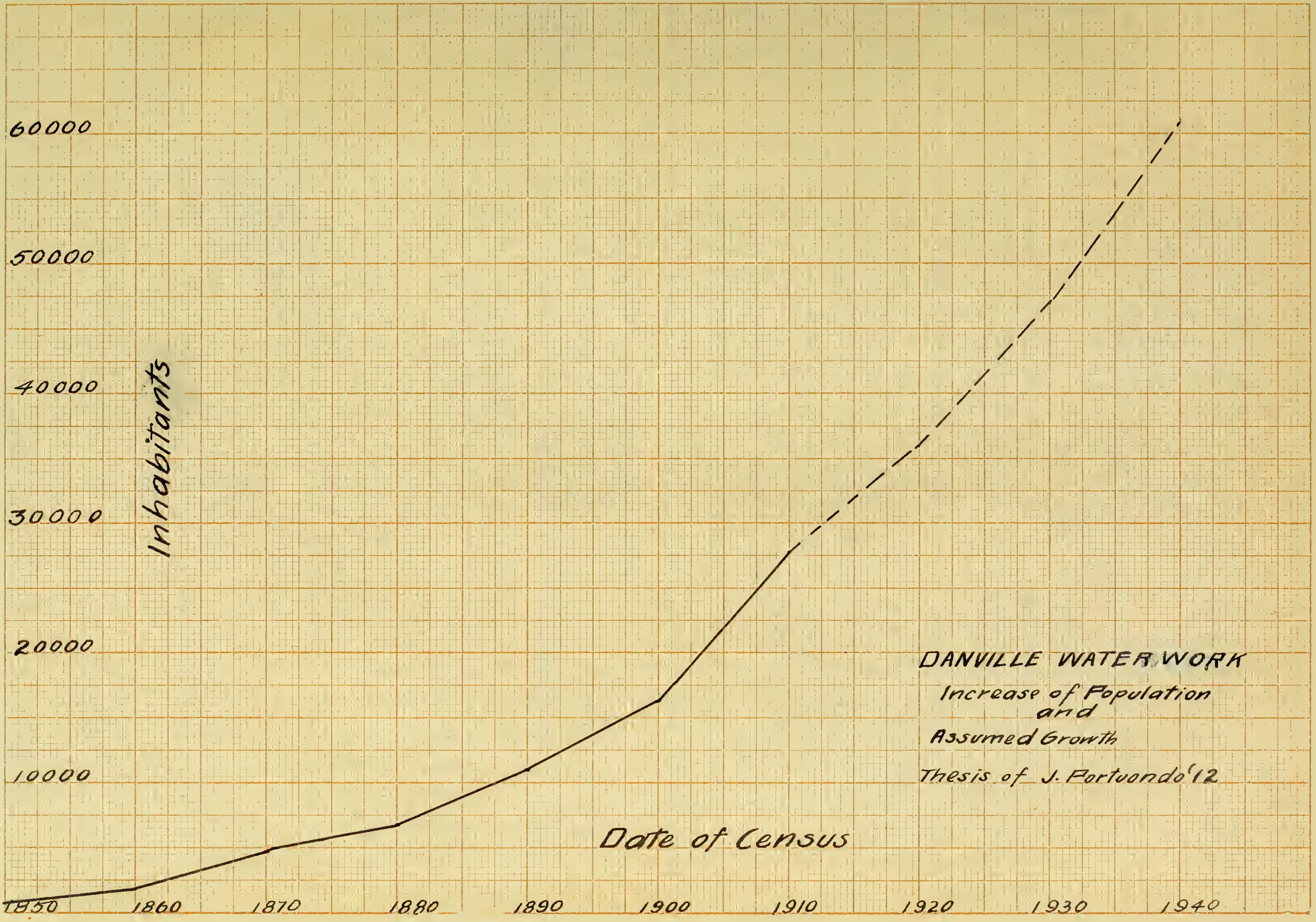
Another item affecting the daily consumption is supply for fire protection. In the case at hand the number of streams required for fire protection was computed to be $N = 2.8\sqrt{30}. = 15.$ Fifteen streams at 250 gallons per minute will discharge 225,000 gallons in one hour. Then the total rate of consumption is 219,000 + 225,000 = 444,000 gallons per hour, or 10,600,000 gallons per day.

Since the present number of inhabitants to be supplied is 9,000 and the maximum 30,000 it is natural that in selecting the pumps it will be more economical to buy pumps to supply the present demand and add to the capacity as needed. For a population of 12,000 the average demand will be 1,200,000 gallons per day, the maximum domestic demand will be 2,100,000 gallons per day, the maximum demand including fire service will be about 5,500,000 gallons per day. Two pumps of about 5,000,000 gallons capacity are to be provided at the present time and another pump added when necessary.

There are three items affecting the amount of work to be done. The energy employed in imparting velocity, in overcoming frictional resistance, and that used to overcome the resistanc of gravity. The energy expended in produced velocity may readily be transformed to pressure energy by the expression,

$$h = 2\frac{v^2}{g}$$

h = pressure head.
v = velocity.



U. OF I. S. S. FORM 3

g = acceleration due to gravity.

work = q w h and calling h, h_2, and h_3 respectively the three stated losses:

$$\text{Work} = q\ w\ (h_1, + h_2, + h_3)$$

$$= q\ w\ \left(\frac{v^2}{2g} + f\ \frac{e}{d}\ \frac{v^2}{2g} + h_3\right)$$

The size of the main pipe to be used depends upon the cost of pumping against friction, loss, and the cost of the pipe. A 20 inch pipe will be used near the pumping station to the forst branch lines. A rough calculation gives probable friction losses of 13 feet. The difference in elevation is 20 feet. The pressure in the mains except, in time of fire, will be 35 pounds or 80 feet. Other losses are practically zero. The total head against which we have to pump is 113 feet. At time of fire the friction loss will be increased and the pressure of the hydrants will be 75 pounds. Then the total head against which to pump will be about 220 feet.

In choosing pumps, Condensing Low Duty, Compound High Duty, and Triple High Duty were considered. In comparing the cost of the pumps the following values were taken:-

Cost of 5,000,000 gal. Triple High Duty Pumps	$ 24,000
" " " " Compound " " "	16,500
" " " " Triple Low " "	14,000
" " Boilers	$ 20. per H.P.
" " Coal	1.50 per ton.
Interest	5%
Depreciation on Pumps	5%
Maintainance of "	3%
Depreciation of Boilers	5%
Maintainance of Boilers	5%

Salaries and other costs were assumed to be the same for all pumps.

The average duty per 1000 lb. steam throughout the year was assumed to be:-

Triple Low Duty	25,000,000
Compound High "	35,000,000
Triple " "	45,000,000

	Triple Low Duty	Compound High Duty	Triple High Duty
Cost of Coal per annum.	$2140.00	$1470.00	$1140.00
Interest, Maintainance and Depreciation on Pumps.	1820.00	2145.00	3120.00
Interest, Maintainance and Depreciation on Boilers.	189.00	135.00	105.00
Total	$ 4149.00	$3750.00	$ 4365.00

Boiler capacity would have to be furnished for fire supply regardless of the style of pump used so the relative cost of boilers should probably be ommitted from the figures. The compound high duty pump is the most economical and one pump of this kind will be used. The other pump will be a low duty pump suitable for fire service. The compound high duty pump will be used all the time when possible.

Location of Plant.

Two locations for dam and pumping plant were considered and are shown on the plan. The cost of the dam of the down stream location is much less than at the upper one. All other costs would be nearly equal. For that reason the lower one was chosen and its construction advised unless Boring in the location of the upper dam shows a more impervious material.

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